proActive

The official industry newsletter of Lotus Engineering

Issue 16
September/October 2006

British, racing and very green

Energy utilisation and future automotive fuels

Welcome

A frequent preconception is that green cars are worthy but dull. Anyone who has driven the Exige 265E biofuel powered car will most certainly tell you otherwise. I'd be surprised if you haven't seen this high-performance, environmentally friendly prototype in the press already, but here in proActive Geraint Castleton-White tells its story.

Biofuels will certainly play their part in powering cars in the future. Fossil fuels, which are the basis of current automotive transport, have a finite life and will eventually be replaced. But where will we get our transport energy in the future. Richard Pearson discusses some of the potential scenarios for future energy economies.

In our continuing efforts to develop more environmentally friendly vehicles, Lotus Engineering is increasingly collaborating with other organisations. We are fortunate that the East Anglia region of the UK where Lotus has its headquarters is a hotbed of activity for the promotion of low $C0_2$ technology. James Beal of Renewables East, one organisation working in this field, shares his perspective on reducing $C0_2$ and how the East of England is working towards this.

Standing back and looking at the global automotive marketplace, Tony Lewis explores the various approaches adopted by major OEMs for reducing $C0_2$ and powering the cars of the future.

We've had feedback that many of you like to keep an eye of what's going on in other parts of the Lotus organisation so we've provided brief summary of a few the things that have happened in the last few months. Hopefully, this will become a regular feature.

I hope you find this latest issue interesting. Enjoy.

Peter Morgan, Marketing Manager, proActive Editor

Contents

September/October 2006

JAPAN: Nissan to trial 'intelligent transportation'

Nissan Motor next month begins testing a newly developed intelligent transportation system which allows vehicle-to-infrastructure communication to help reduce traffic accidents and ease congestion.

The test, which is being conducted to evaluate the receptivity of drivers to such a system, will run from 1 October 2006 until the end of March 2009 in Kanagawa prefecture, about 15 miles (25km) southwest of Tokyo. About 10,000 drivers, who must be subscribers to Nissan's Carwings navigation service, are expected to participate in the test. Applications for the test will be accepted starting in late September.

The road traffic system uses information obtained from nearby vehicles and roadside optical beacons to alert drivers to potential danger from approaching vehicles. The information is received by an onboard antenna.

In addition, the system uses the information to warn drivers when they are speeding in school zones. It also provides drivers with fastest-route information using probe data – information on the position and speed of vehicles obtained by wireless communications technology.

The system warns of possible collision via sat-nav screen

System components to be trialled include:

- Vehicle alert - this system alerts drivers to the presence of vehicles moving too fast at blind intersections. For example, if the system determines that a car is approaching a driver too fast from the left, a buzzer will sound and a voice recording will call out: *"Car approaching from left"*. At the same time, an image of an approaching vehicle will appear on the driver's navigation screen. The system will also alert a driver when it detects that he or she is approaching a stop sign or red traffic light too fast.
- Speed alert - warns drivers when they are speeding in a school zone. As soon as a driver passes the speed limit in the area, a buzzer will sound and a voice recording will warn: *"School ahead. Watch your speed"*. An image of a school zone sign will also appear on the driver's navigation screen.
- Dynamic route finder - informs drivers of the quickest route to their destination using probe data collected from mobile phones of Carwings subscribers, including taxi owners, as well as vehicle data collected by mobile phone operator NTT DoCoMo. All of the data is sent to Nissan's probe server where it is collectively processed into traffic information. The data is then sent to the driver's navigation screen where it is displayed in the form of real-time maps showing the traffic flow of a greater coverage of roads compared to VICS (vehicle information and communications system), a public service providing similar information via FM multiplex broadcasting (something similar is available free-to-air here in the UK), as well as radio wave and infrared beacons.

The information is transmitted to an onboard antenna

Both the vehicle alert and the speed alert systems will be tested until the end of fiscal year 2007. The dynamic route finder system will be tested until the end of fiscal 2008.

Nissan's system test is being implemented in cooperation with NTT DoCoMo, consumer electronics maker Matsushita Electric and Xanavi Informatics, a maker of vehicle navigation systems and software.

Matsushita Electric has developed the roadside optical beacons for the test in conjunction with Japan's national police agency, the Kanagawa prefectural police headquarters and the Universal Traffic Management Society of Japan (UTMS).

Based on the results of the test, Nissan is planning to implement its system in Japan initially and then globally in the (unspecified) future as part of its efforts to help reduce traffic accidents and congestion.

In Japan, it has set a target of halving the number of traffic fatalities or serious injuries involving its vehicles by 2015 compared with 1995.

Source: just-auto.com

US: Mercedes squares up to Honda in diesel technology race

Following Honda's announcement in Tokyo on September 25 that it would sell a 50-state-compliant diesel engine in the US from around 2009, Mercedes-Benz said it would offer similarly compliant versions of its M-, R- and GL-Class sport-utility vehicles with its 'Bluetec' technology diesel engines there in calendar year 2008.

The Bluetec SUVs will be the world's first diesel-powered vehicles to meet the Environmental Protection Agency's stringent BIN5 emissions standards for all 50 US states, Mercedes said.

Honda has said only it will bring its diesel cars to the US market *"within three years"* though US pundits believe it will have its 2.2-litre I4 turbodiesel engine ready for the 2009 model year, which means a launch as early as mid-2008.

> **"The Bluetec SUVs will be the world's first diesel-powered vehicles to meet the Environmental Protection Agency's stringent BIN5 emissions standards"**

Mercedes' 2008 SUV engines will be more advanced than the BIN8-compliant (for the 45 states mandating the federal emission rules rather than the stricter standards imposed by California and several east coast states) Bluetec-powered E-class sedan the automaker is launching in the US next month.

Developed in-house by the automaker, Bluetec is the world's cleanest diesel technology and showcases several state-of-the-art engine and exhaust technologies, Mercedes claimed.

However, US auto critics have already noted that the Bluetec technology requires the addition of urea solution injection to achieve the tough BIN5 emissions standards – to achieve a critical NOx reduction – and this adds to maintenance requirements as the tank must be topped up at regular intervals, expected to be about the same as US oil change intervals (usually shorter than those automakers recommend in Europe).

Launching new diesels in the US

The Honda system, in contrast, uses a new catalytic converter technology to reduce the NOx emissions, without the use of urea injection.

According to Mercedes, the Bluetec-powered SUVs for launch in 2008 will showcase 'AdBlue injection', a process that adds precisely measured quantities of the urea-based solution into the exhaust stream to help reduce nitrogen oxide emissions by up to 80%.

"Today's announcement represents a significant step for the future acceptance of diesel vehicles in the US market, which can contribute to significant fuel savings and a reduction in oil imports," Mercedes' US unit said in a statement.

"This fact was confirmed in a study by the Environmental Protection Agency in 2004. Margo Oge, head of its office of transportation and air quality, concluded that if only one-third of all light-duty trucks in the US were operated with modern diesel engines, the country would save 1.4m barrels of oil per day - equal to the amount of oil the US currently imports from Saudi Arabia."

Mercedes claims the E320 Bluetec-powered sedan due out next month uses a three-litre V6 turbodiesel to deliver the *"the low fuel consumption of a four-cylinder compact combines with "the powerful torque of a large V8 engine"*. It is currently the only diesel-powered vehicle sold in the US certified to the BIN8 standards.

Source: just-auto.com

US: Tesla electric sportscars 'sell out'

Tesla Motors, creator of an all-electric sports car, has already taken US$100,000 deposits for its first 100 cars, according to CEO Martin Eberhard.

The deposits guarantee that buyers will get the cars, due out next year.

"All 100 are gone," Eberhard said, according to reports.

The company launched the car in Santa Monica, California, on 19 July, by which time 37 people had already placed deposits. Many early buyers, such as Google founders Larry Page and Sergey Brin and eBay co-founder Jeff Skoll, are investors in Tesla and, so far, only a few cars have been fully completed.

Tesla Roadster

Tesla Motor claims that its roadster can do 0-60 mph in about 4 seconds with a top speed of over 130 mph. The firm also says that because the car has no clutch and a very wide, flat torque curve, the Tesla Roadster accelerates instantly for an enjoyable performance drive.

However, the claims on range between charges – seen as a weakness on plug-in electric cars - have also attracted attention. Tesla says that range depends on driving style and conditions, but that *"on the EPA highway driving cycle we expect 250 miles on a charge".* Many existing plug-ins manage only around 40 miles.

Deliveries are expected to begin in the autumn of 2007 in the US (currently California, and the metropolitan areas of Chicago, New York City and Miami, where aftersales backup is being provided). There are no plans to offer the Tesla outside of the continental US.

The Tesla Roadster will be assembled on a contract basis by Lotus in the UK. Lotus Engineering has also been involved with the car's development and supplied the initial chassis which was then modified further by Tesla Motors engineers.

Source: just-auto.com

GERMANY: VW eyes contract assembly

Volkswagen's management is considering the possibility of assembling vehicles on behalf of other automakers, according to *Automobilwoche.*

Such a move would help Volkswagen improve its capacity utilisation.

In addition, Volkswagen is considering restructuring vehicle assembly shifts to dramatically improve efficiency.

The proposals were made by CEO Bernd Pischetsrieder in an effort to move forward on-going talks with unions about securing jobs at six German plants.

In an interview with *Automobilwoche* during the IAA commercial vehicles show in Hannover, Bernd Wiedemann, CEO of VW commercial vehicles, confirmed an interest in contract assembly.

> *"Volkswagen management is also reported to be considering building the next-generation Audi A3 at Wolfsburg"*

However, he noted that the main commercial vehicle plant in Hannover is fully used, with the T5 van range, a new VW pick-up planned and a contract to build and paint the bodies of the new Porsche Panamera, which is due to go on sale from 2009.

Volkswagen management is also reported to be considering building the next-generation Audi A3 at Wolfsburg, to maximise the production and component synergies with the Volkswagen Golf which shares the platform along with other VW group models.

The A3 apparently has more in common with the Golf than the Audi A4 and, by building the model in Wolfsburg, Audi would gain some much-needed capacity at its Ingolstadt plant to build niche models such as the upcoming Q5.

Source: just-auto.com

British, racing and very green

Can saving the planet be fun? Well if you work at Lotus the answer is yes.

A cornerstone to Lotus Engineering's future plans is a deep involvement in applying and developing technologies that reduce CO_2 and reliance on fossil fuels.

There is a great deal of discussion and debate regarding the contribution that motor vehicles emissions have on the environment and global warming; this has sometimes spilled over into open criticism of the use of vehicles for anything other than important transport needs and the debate as to what type of vehicle is suitable.

Biofuel Exige 265E

This at first appears to be in conflict with the desire to own and drive a sports car, even more so when the vehicle is used for track days and pure enjoyment. The Lotus philosophy of performance through light weight has already embraced the concepts of downsizing powertrains whilst maintaining maximum driving pleasure. The current Elise R has a 1.8 litre 189bhp engine, performance is 0-60 in 4.9 sec and fuel economy is 41.4mpg

Against this backdrop and with the announcement of increasing biofuel infrastructure Lotus decided to look at ways to demonstrate its understanding of what alternative fuels could achieve and the techniques and technologies required to produce production vehicles that are both fun to drive and environmentally friendly.

As an engineering consultancy we have a desire to promote these ideas not only internally at Lotus, but also to a worldwide audience.

The obvious choice for our research was one of our own vehicles. We recently launched the Exige S, which produces 220 bhp using a 1.8 litre supercharged engine. It made sense to try and use this vehicle and to match or better the performance using a biofuel. The fact that the vehicle is pressure-charged provided even more opportunity to exploit the performance characteristics of a high-octane fuel.

The next question was: which fuel? The area of alternative fuels is currently very exciting and fast-moving. Our fuels experts highlighted a number of potential avenues which included methanol and biobutanol.

We concluded that using biobutanol would not stretch our engineering team as it has similar characteristics to gasoline and would deliver similar performance to the standard vehicle. This and the current lack of availability led us to decide not to proceed with this fuel for the time being. Methanol has for many years been the preferred fuel for some racing series, primarily due to the high octane rating, allowing significant performance increase. It can be produced in a number of ways and the fact that it can be synthesised from methane (natural gas) means that it could be available in a number of territories across Europe and the World. This was considered an area for future research and coupled with the fact that it had no proposed manufacture or supply infrastructure methanol was rejected as the initial fuel for this vehicle.

The growing infrastructure for E85 bioethanol coupled with its combustion characteristics made it the obvious choice as it allowed our engineering team to enhance the engine performance. Coinciding with our review process, Morrison's, the supermarket chain, announced a new initiative to locate E85 ethanol pumps on a number of their supermarket forecourts.

The fuel decided, we started to computer model the engine performance. Our CAE (computer aided engineering) group ran some performance calculations with various injector and intake configurations. The initial calculations looked very promising. The standard powertrain could be enhanced from 220bhp to above 260bhp with little modification to the base engine. In fact, with certain configurations we could achieve even higher performance.

Vehicle performance calculations then showed vehicle performance improvements across the board.

Armed with this information, an enthusiastic team was assembled and tasked with building a one-off engineering demonstrator vehicle to showcase the potentials of the chosen technologies and biofuel.

Lotus has already undertaken a number of alternative fuel projects for clients, but had never focused its attention on promoting the fun aspect of biofuels. The enthusiasm for this project was enormous. It quickly gained senior management support and approval to make it a reality.

The vehicle was taken into the workshop and the engine removed and fitted to the test bed so baseline performance could be measured.

In parallel, the revised intake was designed and fabricated in line with our computer predictions and then fitted to the engine. Our engine management group recalibrated the engine and further performance tests were undertaken. The engine performance met the computer-modelled predictions almost immediately and there then followed a period of further optimisation. The engine was finally removed from the test bed and installed in a modified vehicle. In final trim the engine produced 263 bhp, some 43 bhp more than an Exige S and 74 bhp more than an Elise R.

There was a great deal of excitement and a little trepidation when the day came to start the vehicle for the first time. This soon passed as the engine started immediately and then, after some further calibration tweaks, was taken out on the track for a shakedown.

Safety checks completed, the vehicle was ready for evaluation and sign off. A small group of Lotus personnel were then invited to drive the vehicle and confirm its acceptance, showing that working at Lotus does have considerable perks.

The baseline track drive in a standard Exige S would be exciting enough for most drivers – bordering on ultimate performance. However, the initial impression of the ethanol-fuelled Exige 265E, as it was quickly christened, was a crisp responsive powerful vehicle that universally brought increasing broad smiles from the returning drivers. The performance is awesome!

The final sign off test drive was completed just five weeks after the project was instigated and has resulted in a demonstration vehicle that not only excites the driver but also is at the forefront of environmentally friendly vehicles.

We are planning to develop the vehicle to run on multiple fuels not just E85 ethanol and gasoline.

This avenue of research is very important as further fuel infrastructure could mean that differing countries or even areas within a country will have differing environmentally friendly fuels available. To be able to drive a biofuelled vehicle for long distances in the future, the ability for it to be able to run on different fuels could be crucial. At the moment the limited number of flex-fuel vehicles available default to gasoline. The market is growing rapidly and there are a number of alternative solutions. It is likely the usage will be localised and result in niche markets. Even if overall market penetration remains low there could be almost 100% penetration in a particular region. This is an additional reason why the area of renewable fuels cannot be ignored.

We are pleased that this vehicle demonstrates our engineering capabilities, understanding of flex-fuel vehicles and knowledge of emerging fuel technologies. It also promotes bioethanol as a fuel of choice for the enthusiastic driver as well as the environmentally conscious driver. Optimum performance can be achieved with a pressure-charged engine, although most modern vehicles can be adapted to run on E85 ethanol.

What are we considering in the future? Well, our internal research continues and we are now even better placed to support our engineering customers with flex-fuel solutions and applications of alternative fuels. Lotus is actively pursuing technologies that will improve the efficiency of powertrain in the future. CO_2 reduction is a priority together with technologies that can reduce our reliance on fossil fuels. The problems facing the automotive industry at the moment are challenging. Lotus philosophies, experience and culture are allowing us to play a significant role in supporting future solutions.

The 265E again, from the rear

Will there be further developments in the industry? Definitely, and Lotus is positioning itself to support, develop and innovate solutions for the automotive industry. The subject area is vast, and forming strategic partnerships with manufacturers, Tier 1 suppliers, research institutes and the wider environmental infrastructure is vital.

Geographically, our headquarters in Norfolk are well placed. East Anglia has a unique blend of industrial, academic and agricultural bodies with the potential to significantly contribute to the advancement and promotion of environmentally friendly solutions for the automotive industry.

There is some realignment required in both the auto industry and more importantly through legislation. In these types of vehicles, the quantity of carbon dioxide emitted should be balanced with the consumption of CO_2 in the feedstock. Current tailpipe emission legislation does not account for this. By short-sightedly measuring only the exhaust emissions, we risk restraining a huge opportunity to improve our environment through the use of biofuels. If we can have fun at the same time, that seems like a good thing!

Now, where was that Morrisons supermarket forecourt?

Geraint Castleton-White, Lotus Engineering

Energy utilisation and future automotive fuels

Dominance and Decline of Fossil Fuels

Fossil fuels (oil, natural gas, and coal) accounted for 88% of world primary energy consumption in 2005, with 36% being attributable to oil alone. These fuels are comprised of mixtures of hydrocarbons which, when combusted in order to release energy, are converted largely to CO_2 and water. The depletion of fossil fuels by combustion, and the consequent generation of CO_2, can be considered to be practically irreversible. Nature recycles CO_2 together with water via photosynthesis into new plant life using energy from the sun – the basis of the renewable character of biofuels. It takes many millions of years, however, for vegetation to be transformed back into a fossil-based fuel. This timescale is clearly too large for the process to form part of any viable energy strategy and ultimately requires that a long-term alternative to a fossil fuel-based economy is sought.

Climate Change Concerns

It is difficult to assign much confidence to projections of how long fossil-fuel reserves will last but a shift away from a fossil fuel-based energy economy is inevitable and is being motivated in the shorter term by the growing concern over the impact of greenhouse gases on global climate change and energy security issues resulting from recent political events. The spectre of rising carbon dioxide (CO_2) levels and other greenhouse gases has forced measures to be put in place in order to mitigate their impact such as the Kyoto Protocol, the EU commitment to which requires an 8% reduction in greenhouse gas emissions relative to 1990 levels by 2008-2012.

Growing our future fuels

Pressure is mounting for the European automotive manufactures to reduce the fleet-average CO_2 emissions to 140 g/km by 2008, representing a 25% reduction relative to 1995 levels (see Figure 1). It is unlikely that this target will be met which may prompt the EU to mandate a further target, possibly to120 g/km CO_2 by 2012. The manufacturers of lower powered vehicles will, by making considerable changes to the vehicles, engines and transmissions, be able to comply with this latter level but the makers of predominantly high-power vehicles will face an enormous challenge. Even the adoption of advanced engine and hybrid technology will not reduce the CO_2 emissions levels sufficiently in the highest power vehicles currently on offer. It will be necessary for manufacturers to adopt the use of efficiently produced biofuels or hydrogen generated via renewable energy sources. But the EU needs to adopt criteria which account for the well-to-wheel CO_2 production of vehicles for the benefits of such fuels to be apparent. Then it will still be possible to run high performance vehicles in an environmentally responsible manner.

Along these lines some manufacturers are investigating the use of hydrogen in internal combustion engines. Hydrogen is widely thought of as providing the basis of a future energy economy. It can be burned in gas turbines to generate electricity and in internal combustion engines to provide motive power. It is also required for the operation of fuel cells which are often seen as the long-term replacement for combustion engines. Hydrogen generates no CO_2 emissions in the combustion process in an engine or the conversion process of a fuel cell. However the 'well-to-tank' side of the overall process must be considered.

The Hydrogen Economy

Despite being the most widespread element in the universe, free hydrogen is not present on Earth as a natural energy source. The generation of hydrogen from hydrocarbons or water requires significant energy input. The most common route to hydrogen production is steam reforming of natural gas to produce a 'syn-gas' mixture of carbon monoxide and hydrogen. The carbon monoxide is then combined with water to form CO_2 and more hydrogen. This process is commercially well established on a large scale in the chemical industry but clearly generates greenhouse gas emissions. Alternatively water molecules can be split by electrolysis into hydrogen and oxygen. Clearly using renewable fuels or nuclear energy to generate electricity for electrolysis produces much lower levels of greenhouse gases and is the only viable long-term basis for hydrogen production.

Hydrogen, however, is not a convenient energy storage medium. Its low energy density, high volatility, diffusivity and wide flammability range mean that its storage, transportation and distribution are problematic and expensive. Development of a centralised hydrogen economy would require the construction of an entirely new dedicated infrastructure at huge cost. For transport applications, the use of on-board reformers or a network of hydrogen-producing refuelling systems could be adopted but on-board reformers have been found to have fairly

low efficiencies. Vehicles using this technology are more energy-intensive and produce more CO_2 emissions than generating hydrogen centrally and, if fossil-based fuels are used for the reformer feedstock, are not viable in the long term. Using the generated hydrogen to feed a fuel cell is reported not to offer any benefit in greenhouse gas emissions compared with gasoline in advanced internal combustion engines or hybrids.

Hydrogen can be stored on board the vehicle either as a compressed gas at ambient temperature, or in liquid form at – 23O C in a cryogenic tank. Even in this latter state it has a volumetric energy content which is four times lower than gasoline. The liquefaction process is energy intensive, complex and expensive – about 30-40% of its energy content is required for liquefaction. It is thus the infrastructure problems and the unsuitability of hydrogen as a transport fuel which severely limits the potential development of a 'hydrogen economy'.

An ethanol manufacturing plant

The 'methanol economy' stores energy generated via the conversion of nuclear and renewable sources in the convenient form of a liquid medium. It is similar to the basis of the long-term hydrogen economy but without the distribution and transport problems associated with a gaseous fuel. Methanol and DME are excellent fuels for internal combustion engines, and direct-methanol fuel cells (DMFC's) have recently been developed.

Methanol (CH_3OH) has very similar properties to another alcohol fuel, ethanol (C_2H_5OH). Both have high research octane numbers (106 and 109 respectively) and this enables internal combustion engines running on these fuels to achieve high thermal efficiencies and high performance levels. Engines optimised to exploit the beneficial properties of running on alcohol fuels can have high compression ratios giving improvements in efficiency across the operating range compared with engines running on gasoline. These effects are particularly advantageous to pressure-charged engines where, for a given performance level, the lower boost pressure required because of the increased charge air density, and the higher octane number, would enable increases in compression ratio relative to using gasoline fuel. Therefore alcohol-based fuels would be complimentary to the downsized engine concepts which are being introduced in order to improve fuel economy.

Whether alcohol-based fuels feature in the future of the transportation sector in only in a relatively minor or a geographically specific way, via the biomass route, or if they do indeed form the basis of the global energy economy, their potential benefit in modern engine architectures is of great interest. It is important to begin developing new engine technologies now which are compatible with the fuels that may emerge from the shift away from a fossil-based energy economy and are viable fuels for the transport sector. Although there is considerable uncertainty regarding the choice of fuel on which to base the future global energy economy it is clear that diverse sources of energy will need to be exploited in order to supply the 6 million tonnes of transport fuel used currently per day. Despite a 'food versus fuel' compromise ultimately limiting the amount which can be globally produced, biofuels will undoubtedly play a significant part in the future energy economy due to their potential to provide significant reductions in CO_2 emissions via the renewable aspect of their production and the photosynthesis process. Although there is insufficient land area for biofuels to globally replace oil and gas, in large countries with low population densities, biofuels could replace a significant amount of motor fuel demand.

BMW 745h

Alcohol Alternative

Perhaps a more feasible long-term replacement for the current fossil-fuel-based economy is one based on methanol. This has been proposed by the University of Southern California as a potential route for the global energy economy to reduce and ultimately liberate itself from its dependence on fossil fuel reserves while mitigating the effects of climate caused by the excessive generation of CO_2. Being a liquid fuel, methanol can use conventional storage, distribution and transport infrastructures with minimal modification.

The concept of the methanol-based economy is based in the short-term on the efficient direct conversion of natural gas to methanol or dimethyl ether (DME) in addition to the recycling of CO_2 captured from the exhaust gases of fossil fuel-burning power generation plants and other industrial sources. However, in the longer term catalytic and electrochemical methods are being developed to recycle CO_2 from the atmosphere so that

it can be combined with hydrogen to produce methanol. The hydrogen required for this process must ultimately be produced by a combination of nuclear and renewable energy sources, with the former option being the only feasible large scale non-fossil fuel based source of energy in the medium term. This strategy enables a carbon cycle to be envisaged, as shown in Figure 2. The cycle also provides a route for the production of plastics and hydrocarbon chemicals since methanol can be converted to ethylene or propylene. This 'outflow' from the cycle accommodates an 'inflow' in the form of CO_2 generated from the combustion of fossil-fuels.

Alcohol Fuels in Vehicles

The technology required to run engines on methanol has been developed previously, particularly by the motor racing community in the US. And bioethanol has been produced in Brazil since the late1970s when it was encouraged by the government. Sugar cane has a very high crop density: up to 80 tonnes per hectare can be produced, compared with between 10 and 20 tonnes per hectare for most plants cultivated in a more temperate climate. The availability of cheap wages in Brazil makes harvesting sugar cane considerably less CO_2 intensive than wheat in more developed countries.

The additional greenhouse gas impact of fertilisation, harvesting, transportation, fermentation, and distillation must be accounted for. The figures quoted for the reduction in vehicle greenhouse gas emissions using biofuels vary significantly depending on the manufacturing methods and the fate of the by-products. For bioethanol produced from sugar beet and wheat, with current technology and assuming the most economical way of utilising the by-products, a saving of just over 30% of well-to-wheel greenhouse gas emissions is estimated, compared with gasoline. Because heat is required at fairly low temperatures for this process ethanol plants are well suited to being mated with combined heat and power schemes – in this case the greenhouse gas reduction figure rises to about 45%. Very significant increases in this figure can be obtained if the by-products are used for energy generation rather than animal feed. It has been estimated that greenhouse gas generation can be reduced by 65% in this way. It is possible that the development of dedicated crops for energy generation via genetic modification will increase the energy efficiency of the process further. The advent of micro-bacterial technology to utilise the cellulose content of plants will enable the use of other types of plants making the fuel production process less energy and CO_2 intensive.

In the US much lower concentrations of alcohols have been used in automotive applications for some time where the term 'gasohol' for the fuel indicates that it is predominantly gasoline with a portion of alcohol as an additive – a typical mix is 90% gasoline with 10% ethanol. With larger concentrations of ethanol attention has to be paid to the materials used in the fuel system of a vehicle. So these low alcohol content fuels provide a convenient route to the use of biomass energy with minimum impact on existing technology. The fact that the use of alcohol in such low concentrations does not significantly affect the properties of the base gasoline fuel means that its only benefit is that obtained from the renewable nature of its manufacture, whereas fuels which are predominantly alcoholic in content enable the additional engine efficiency and performance benefits to be obtained.

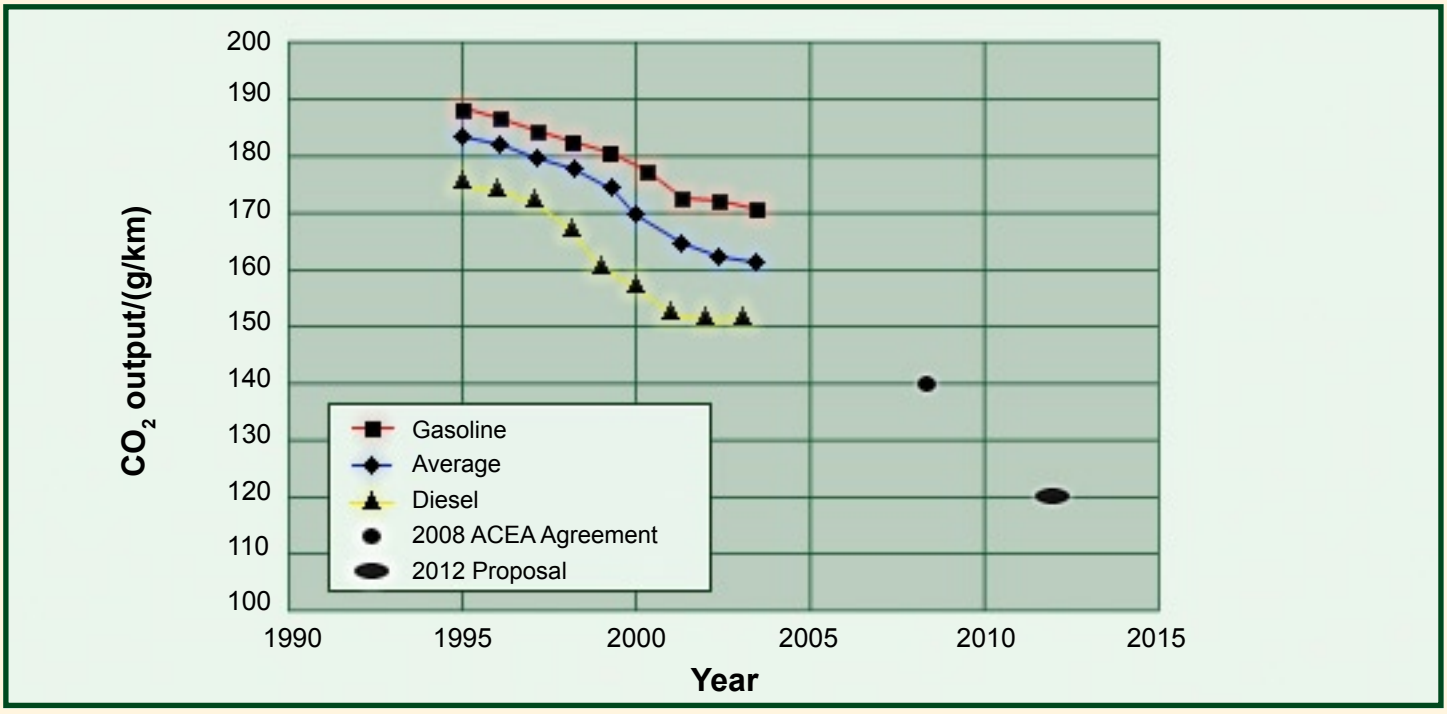

Figure 1. EU fleet-average CO_2 emissions since 1995 (based on SMMT data).

Lotus has found significant efficiency and performance benefits using an 'E85' bioethanol/gasoline blend (a volumetric blend of 85% bioethanol with 15% gasoline), demonstrated by the Exige 265E. But due to the current low level of availability of bioethanol at refuelling stations, vehicles capable of operating on any mixture of alcohol and gasoline are currently required. Consequently Saab and Ford have introduced flex-fuel versions of some of their models. The need to run on fuel mixes which can give substantial variation in properties means that the engine design must be compromised so that the maximum advantages of a particular mix cannot be exploited. If this is to be avoided some sort of variable compression ratio mechanism must be adopted so that the geometric compression ratio can be modified as a function of fuel type and load on the engine, an avenue of research activity for Lotus Engineering.

Taxing and Selling Alternative Fuels

In the gradual transition away from fossil fuels, a wide variety of options may become available, including natural gas, LPG, bioethanol, biobutanol, methanol, biodiesel, DME, and possibly hydrogen, in addition to gasoline and diesel themselves, and mixtures of the liquid fuels. This proliferation of liquid and gaseous fuels with a variety of different physical and chemical properties will require the re-assessment of the way in which fuel is valued. The intrinsic value of the fuel is its energy content and this property should dictate the way in which it is taxed and priced. Naïve quotation of fuel consumption in miles per gallon or litres per 100 kilometres produces unduly pessimistic figures for bioethanol fuelled vehicles since 1 litre of E85 contains only about 72% of the energy content of 1 litre of gasoline. Distance travelled per unit of energy consumed is the only sensible metric when comparing vehicles running on different fuels.

The Future

Careful analyses, which include the energy requirements of the design, development, production, maintenance, and disposal processes of the vehicle, in addition to fuel exploration, production, transportation and distribution, and the vehicle usage, are necessary in order to consider the full impact of the vehicle in energetic and environmental terms. The way in which the fuels are taxed and priced needs to considered so that the consumer can correctly assess the merits of the fuels on offer. The often-assumed end-game of the advent of a hydrogen economy is not a certainty – alternative approaches offer significant advantages in terms of infrastructure costs and ease of distribution and storage.

Richard Pearson, Lotus Engineering

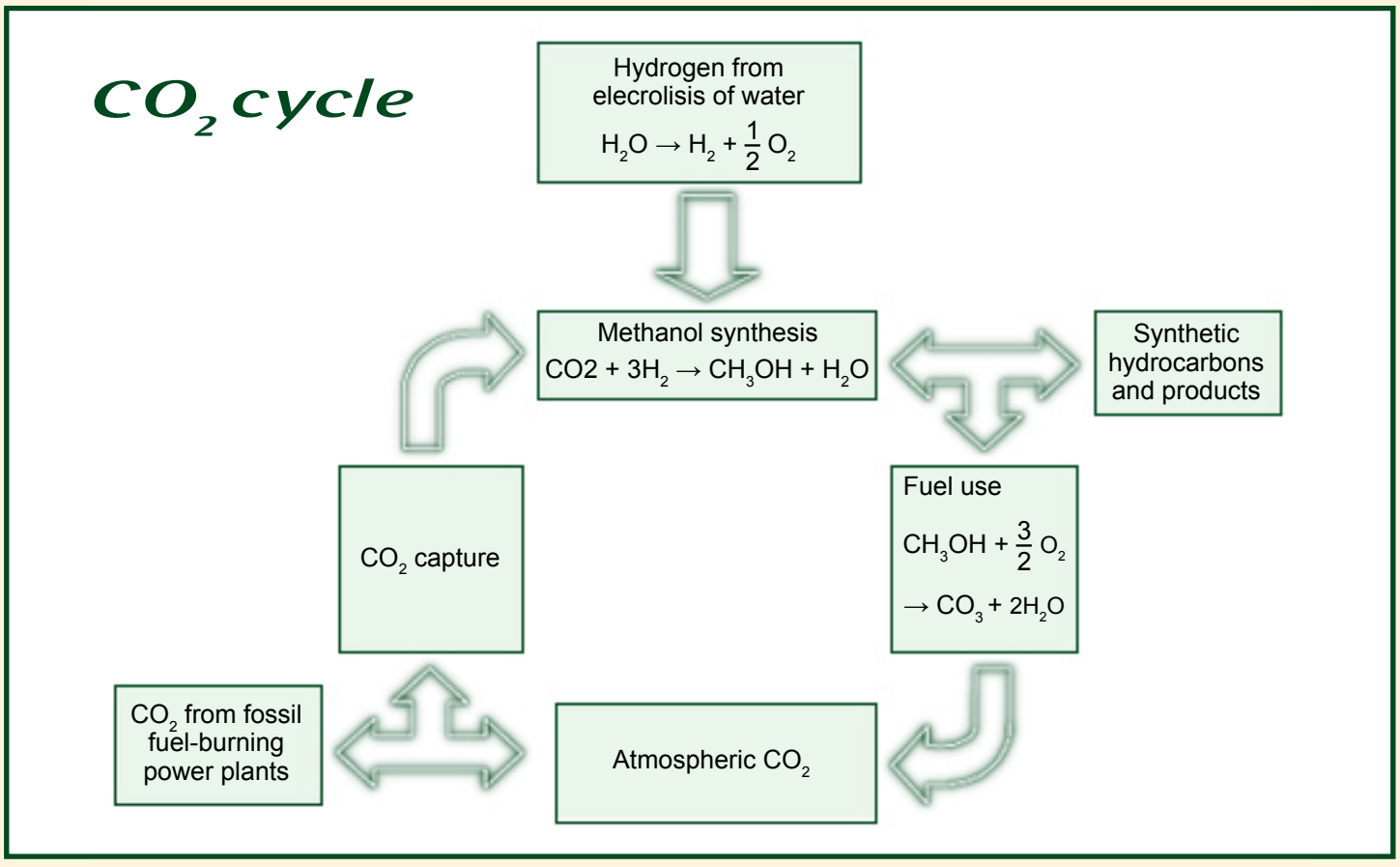

Figure 2. CO_2 cycle using methanol with fossil fuel consumption and synthetic hydrocarbon production

Fuel for thought

Automakers are unanimous on one thing – and probably only one thing: there has to be a varied approach towards future powertrain technologies. This diversity of views is being driven by technology, individual markets, political will and legislation.

Most believe that hydrogen is the most likely fuel of the future but its everyday practical use is still a very long way off because of manufacturing, storage, distribution and refuelling issues. The short to medium-term technology is also splitting between pure electric power, hybrid electric shared with diesel or petrol, or further refinements of diesel and petrol engines.

Even the fuel going into diesels is changing from pure heavy oil to blends with synthetic and biomass derived alcohol is being promoted for mixing with conventional unleaded petrol in some models.

The technical complexities are being matched by political parameters with California almost going it alone in the US and insisting on more electric vehicles, while Northern European countries are throwing their weight behind flexible fuel biomass models as favoured in South America.

The rest of the European continent is really homing in on advanced diesel engines, while China's booming car market is a petrol economy.

Diesel for Europe, petrol for China

As if that is not enough to tax the technicians, we are also seeing efficiency being sought through better design, materials, construction and components such as multi or variable speed transmissions, sophisticated electronics, brakes and tyres.

Nissan, which likes to think it is at the forefront of CVTs (continuously variable transmissions) says it will sell one million cars with CVTs in 2007 – that has the same advantage as 200,000 hybrids in terms of $C0_2$ reduction.

JD Power estimates that there will be one million hybrid units in 2011 and suggests a scenario where hybrids will be strong in the US while Europe will concentrate on refined diesels and direct injection engines.

It is not only the automakers themselves who are investigating the fuels and systems of the future as many individual consultancies and engineering companies, even farmers' co-operatives, are turning their attention to the issues.

Governments which recognise they need to keep transport moving to maintain economies and revenue also appreciate there is a majority of citizens who depend on public transport so mass transit systems need updating but all this has to be achieved by minimising environmental and health impacts so finance is becoming a big issue.

The UK government's system of tax penalties for vehicles emissions is likely to be adopted by more countries around the world as they struggle to cope with so many conflicting demands.

Not only must we get the most out of our cars, but also our roads, and the EU has allocated billions of euros to research a Continental GPS system which would enable more vehicles to use each kilometre and with reduced danger of collision, through interacting with a vehicles systems.

At this year's British international motor show in London, Ford took the wraps off an ice-sculpture of the Focus CC to illustrate its commitment to reducing global warming with a £1 billion investment across its core and Premier Automotive Group brands to slash CO_2 through advanced engineering.

"Climate change is one of the greatest single challenges facing the auto industry and society today," Ford of Europe and Premier Automotive Group Chairman and CEO Lewis Booth said at the unveiling. *"A broad business strategy that serves all our brands is the only way we can achieve the level of improvement in emissions and fuel economy required."*

Lewis Booth represented the European Automobile Manufacturers Association (ACEA) on the European commission-led CARS21 High Level Group that last year recommended an integrated approach between automakers, oil companies, governments and consumers to reduce CO_2 emissions.

Ford's Chief Technical Officer Richard Parry Jones said, *"We believe we have to follow a multiple technology strategy for three reasons.*

"First, there is no single technology on the horizon that will enable the automotive industry to play its full part in stabilising levels of atmospheric CO_2.

"Second, we also cannot say for certain which way the market will go in the future and how much regional differences will play a part. Ultimately it will be customers who decide which technologies best suit their needs.

Lexus IS 220d

"And finally, as vehicles get cleaner and cleaner the technological challenge to eek out further improvement increases."

Toyota has been in the forefront of affordable hybrid technology and it has been steadily investing in systems. It aims to have ten hybrid vehicles available by 2010, including five in the UK, and they will account for up to 25% of global sales by the early-mid 2010s. Toyota has sold more than 550,000 Prius cars since 1997.

Like Ford, it is not putting all its eggs in one basket and has also gone down the route of super-clean diesels. The D-CAT ultra clean diesel can simultaneously reduce NOx and particulates and is available in the 2007 Avensis, Verso, RAV4 and Lexus IS 220d models.

Also, as part of this effort, a new 1.8-litre petrol engine and Continuously Variable Transmission (CVT) have been developed for Toyota compact and midsized passenger vehicles.

As a target for 2010, Toyota aims to achieve emissions levels that are 75% lower than the 2005 emissions standards set by the Japanese Ministry of Land, Infrastructure and Transport's Approval for Low emission vehicles and to exceed the level called for by the Japanese 2010 fuel efficiency standards by 10% or more for most passenger vehicles.

Toyota aims to make hybrid technology much more widespread by doubling the number of hybrid vehicles by the early 2010s. It will also advance its research and development of plug-in hybrid vehicles (charged from an external source) and is currently developing a next-generation vehicle that can extend the distance traveled by the electric motor alone, further contributing to the reduction of CO_2.

Regarding Toyota's introduction of bioethanol compatible vehicles, Toyota has achieved the technology to allow all its petrol engines to run reliably with 10% bioethanol content. In the spring of 2007, Toyota plans to introduce to the Brazilian market (where this fuel is widely used) flexibly fuelled vehicles that can run on 100% ethanol. For the US, Toyota is considering the introduction of flex-fuel vehicles in consideration of policies to promote bioethanol fuels.

Toyota plans to further it's development of fuel cell passenger vehicles and has successfully reduced by a large margin the time required for sub zero startup and has achieved start up at minus 30 degrees C Celsius.

Volkswagen chairman Dr Bernd Pischetsrieder said it was keen to adopt a *"level headed and leading edge"* approach to future technology. He said to do this required staged progress.

"It relies on three principles: increasing efficiency of the powertrain while reducing tailpipe emissions; incorporating alternative energy sources in the fuel production process; and developing fuels that are CO^2-neutral and can be used in existing engines."

A level headed approach to the future

He also said that biomass offered the greatest opportunities because it could be made from so many raw materials including waste, plants and wood products and it was extremely safe to handle and use.

Development of this biomass *"designer fuel"* would lead to a new a family of fuels and powertrains with specific properties and advantages, he added.

Also in Germany, Mercedes-Benz and BMW are adopting a broad-based development programme with advanced diesel engines taking the lead while hydrogen and hybrids are also being researched.

For these, dramatically improving the performance is as important as environmental and efficiency issues as they want to maintain a reputation for sportiness so the MB SLR and CLS are the first to get the latest generation of CGi engines with a further series being planned for Europe in 2008 as well as the US which dramatically cut NOx.

In the UK, the 'smart ev' is a running prototype electric version of the ForTwo developed with a UK consultancy and being trialled under closely controlled conditions with small fleets in urban areas where it can be charged on a normal domestic supply and run for over 50 miles per charge.

In the area of alternative powertrains, the BMW Group is investing in the hydrogen combustion engine as the engine concept of the future. In comparison to fuel cells, the hydrogen combustion engine has a higher power density, lower costs and supports the usual driving dynamics.

To guarantee the individual mobility of customers over the long term as well as reduce emissions, especially CO_2 emissions, the BMW Group is focusing on hydrogen generated from renewable energy sources.

Smart EV - 70 mph, 72 miles/charge

The two German companies have also joined forces with General Motors specifically to develop hybrid diesel electric technology for larger vehicles such as SUVs, buses and delivery vehicles requiring consistent stop-and-start driving. The cost of developing and making such systems can be prohibitive and this opens up another element of the changing face of future technology.

Chevrolet Tahoe 2007

Because of cost and complexity and comparatively smaller volumes than internal combustion engines, we are seeing greater collaboration on projects to share expenses and pool knowledge for optimum benefits. It is also happening with shared conventional powertrain development such as the Fiat and GM projects and Ford PSA engines.

With its huge US sales base, GM is, for the immediate future, refining its internal combustion engines and looking at biofuels and biogas, but it has also committed to hydrogen introduction and will have a workable system in place by 2010 with water-only emitting hydrogen models in showrooms a few years after.

Mazda is already evaluating a hydrogen-powered RX-8 in Norway and Ford has been testing a Focus using the fuel in Germany. Mazda certainly believes that hydrogen vehicles are the best solution and not necessarily the most expensive option that others highlight when promoting alternatives, and part of its assessment in Northern Europe will be to look at the total overall cost.

There are some who remain unconvinced about the true cost of hybrid technology, citing production cost and disposal as elements which should be included in the overall efficiency and pollution calculations.

Agreeing to disagree seems as acceptable as the variety of powertrains we will be using every day at some point in the future.

Tony Lewis

Group News – What else is happening at Lotus

Going forward, each issue of proActive will take a brief look at other events happening within Group Lotus, starting this month with the summer activities in Lotus Cars and Motorsport

A busy summer

The Summer months have proved to be as busy as ever for Lotus Cars with a wide variety of national and local events taking place to support both new and current product.

The moving of the British International Motorshow to its new home in London commenced with a parade of cars through some of the capital's high-profile locations on a sunny Sunday prior to the motorshow.

Lotus Cars provided a mixture of new, current and 'not yet launched' product in the form of: Esprit S3, Elise S1, Elise R, Exige S, Europa S and a 340R. An Elan S1 and a JPS Europa were also kindly loaned by a customer while the owner of a Lotus Cortina at the event remained anonymous!

Having rendezvoused on the A14 at Newmarket on a hot Sunday morning, the group proved an interesting sight for holiday traffic travelling to London. Making use of the Europa's standard-fit satellite navigation, it arrived at the parade meeting point of Park Lane southbound (thankfully closed by the Police for the event)

With the parade entitled '100 Years of Cars', the event was divided into decades with the oldest taking the lead and the newest at the back. With each Lotus residing in its respective decade the parade set-off down Park Lane, eventually finishing along Whitehall.

Lotus Europa

"For Lotus enthusiasts, the event allowed most people their first opportunity to see a new Europa on UK soil as well as seeing rare and older product"

Thousands had turned out to watch the event and at many points along the route were more than three-deep. For Lotus enthusiasts, the event allowed most people their first opportunity to see a new Europa on UK soil as well as seeing rare and older product.

The next two weeks saw many from Lotus and its UK dealer network working on the stand at the British International Motorshow. With five cars on display, including the new Elise S and Europa S, hospitality and the opportunity to purchase a wide range of merchandise, the Lotus stand was permanently busy. A queuing system allowed visitors the opportunity to view and sit in all the cars on show without feeling like being in the middle of a rugby scrum as well as allowing stand staff the ability to talk at length with those who were interested in finding out more about the Lotus range.

Almost without pausing for breath after the last customer had (eventually) left the stand, attention turned to a new campaign – the Lotus Summer Festival. Not content with launching one new product we decided to 'change the rules' and launch both the new Elise S and Europa S within a five-week period as well as highlighting the Exige S in the middle.

The event was promoted in a wide range of print media and was supported by direct mail and a range of three unique viral ads that can (still) be downloaded from the campaign's web-site www.lotussummerfestival.co.uk. Each weekend event gave the opportunity for dealers to invite current customers as well as new prospects to test drive the range of new product available.

LOTUS SPORT NEWS

The Lotus Sport Exige, the 400bhp 850kg GT2 specification race car debuted in 2005 and built by Lotus Sport, Hethel, UK, won the Petronas Primax 3 Merdeka Millennium 12 Hour Endurance race trophy at the International Sepang circuit, Malaysia on Sunday 27th August. In doing so it became the first ever vehicle to successfully retain the title two years running. The Lotus Sport Exige recorded a new track record of 2:19.874 for Class O Vehicles.

In the British GT Championship, drivers' championship leaders George MacKintosh (41.5 pts) and Sam Blogg (41.5 pts) in the Lotus Sport Exige GT3 are now 0.5 points ahead of Leo Machitski (41 pts) in the Aston Martin DBRS9. Lotus Sport (46.5 pts) leads the manufacturers championship by 15.5 points over Aston Martin (31 pts) going into the final GT3 race at Silverstone on the weekend of 24th/25th September.

Source: Simon Croft and Louis Kerr

Lotus Sport Exige GT2

The unavoidable truth

James Beal of Renewables East discusses the impact of climate change and how the East Anglia region of the UK is working to address it.

Climate Change is happening and as a direct result of anthropogenic (man-made) greenhouse gas emissions. It was not so long ago that I would then follow this by DISCUSSING the greenhouse effect, climate change and the science behind it. However, the debate has moved on. The science that through burning of fossil fuel we are forcing a change to the climate we enjoy is now accepted.

It is interesting that I first entered this debate over 15 years ago and since then some of the world's leading scientist have been trying to disprove that we are having this impact, with much of this research being funded by multinational oil companies. The debate is now over and is switching to how we mitigate and adapt to the issues surrounding climate change.

Al Gore, the ex Vice-President of the US, has recently launched his new film that describes this as *"An Inconvenient Truth"*. If you are at all wavering as to the challenges we face and the science behind it then I recommend taking the family to see it. It's a challenge we all face and a change we are all experiencing. I think we all have our own little anecdote as to the changing climate. My own is that I remember that my father always used to put the lawnmower away for the winter at the end of September, usually getting it out in late March and early April. In recent years, during warm spells, it has come out in February.

Where the climate change debate now focuses is on the future. There are many advantages to being based at the University of East Anglia but one side-effect a fretful nights sleep having met one or other of the worlds leading scientist on this subject and understanding the consequences that we now all face.

In 2005 it was accepted that the world has warmed by some 0.7°C in recent years. (That might not sound much but usually this amount of warming would take several thousand years). Because there is a time lag between emissions and effect, even if we stopped burning fossil fuel tomorrow the world would continue to warm. Science now tells us that when we get to around 2°C warmer we reach a tipping point. Beyond this climate forcing effects take over and accelerate climate change not matter what we do. There are numerous individual tipping points:

1) The Greenland ice sheet starts melting. This will raise sea levels by metres not the current millimetres. It will also remove a vast area of ice that currently reflects an enormous amount of solar radiation, with this gone the earth absorbed more heat, driving climate change even faster.

2) The tundra/permafrost areas start to melt releasing huge amounts of methane currently secured. Methane is a greenhouse gas 27 times more potent (by weight) than CO_2. This again powers the acceleration of climate change.

3) It is also possible that the direct changes of the global climate will reduce rainfall to the Amazon forest. An accelerated death of the forest releases huge amounts of carbon (and methane) to the atmosphere that is currently held within the forest, and (yes, you guessed it) this accelerates climate change.

4) Due to global climatic shift it is predicted that the natural ozone hole will be extended to cover most of northern Europe.

If I go back to the science of climate change that I started to study 15 years ago, I can also remember the other two *'burning'* issues of the environmental movement at the time, acid rain and the ozone hole. You may recall that acid rain was (simplistically) created by burning of coal in large scale power stations and the sulphur was reacting in rain producing acidified lakes and forests. In a short time, with global commitment this issue has mostly been resolved. You may also remember the ozone hole that was being created by the emissions from deodorant, cleaning products and refrigeration. Essentially CFCs were reacting in the upper atmosphere reducing the ozone protection that we had reducing the radiation reaching the surface. This issue has again been tackled across the globe and we have seen in recent years the ozone layer recovering.

RENEWABLES EAST

Renewables East has been established to champion renewable energy in the East of England, with a goal to secure economic, social and environmental benefits for the region. It was formed by the collective influence of a wide range of stakeholders, from both public and private sectors. Operating independently, a not-for-profit company is now formed, with a Board of Directors and a company membership comprising many of those original stakeholders.

I take heart from the fact that as a global nation we can act together to reduce the impact we are having. The precedent clearly exists and from my interactions across the field of carbon emissions we do have the capabilities to reduce our carbon consequence by the 60% that the UK government is calling for by 2050 when compared with 1990 levels.

Renewables East works across technology areas that are offering a pathway to reduce the emissions. However since being established in 2003 and bringing forward the low carbon solution in the East of England our effective endeavours have been offset by an increase in emissions from transport sector and in particular private car mileage.

Saab 9-5 Aero BioPower

For too long personal transport choices and the car have been left in the too hard box but working with our partners I believe we are starting to see a change of context that I would encourage you all to consider.

Renewables East established the Regional Biofuels Forum that is chaired by Baroness Gillian Shepherd. The forum identified that the East of England with its cultural, environmental and economic heritage embedded in the effective utilisation of its rural land coupled with its recent history of innovation stood it in a strong position to drive forward a low carbon solution to transport fuel. Basically we saw the chance for growing and evolving crops that could be converted into bioethanol (a petrol additive) and biodiesel (a substitute for diesel). These crops would be grown in a cyclical nature. Although the tailpipe emissions would still contain carbon dioxide, because the carbon dioxide was recaptured in the next crop things move towards being carbon neutral. (Its not totally carbon neutral as the tractors, fertilisers etc all rely currently on crude oil).

Following significant research and strong lobbying the government has announced the creation of a Road Transport Fuel Obligation. In 2008 2.5%, 2009 3.75% and 2010 5% of the transport fuel you use for the road will come a biological source or the supplier will need to pay a *'buy-out'* price. Basically this establishes a million tonnes a year market for both bioethanol and biodiesel. In the recently announced UK government *"Energy Review"* given certain issues are meet the government wishes to see this level rise to 10% by 2015.

There are a number of issues this raises. For example do we have enough land to grow these fuels? Last year the East of England exported 3 million tonnes of wheat, if this wheat had been converted into bioethanol then that would have meet 5% of the UK's petrol need. So even without thinking about all this land that is set aside we can see the UK meeting its own needs.

What about stimulating importation of bioethanol from markets such as Brazil? Well Brazil is the world leader in biofuels having produced it commercially for many years as a fossil fuel substitute. However given the currently high global crude price, Brazil's full capacity is being used to meet its own domestic market.

What about the carbon efficiency of biofuels? The US biofuels have a high carbon consquence. It has stimulated a biofuels market purely to give the farmers another market to sell to. The plants that have been built there are focused on creating biofuels without a target to reduce carbon emissions. Drawing comparison between fossil fuel and the US production of biofuels does not give a reflection of the emerging European market that is being created with a carbon pricing structure in place.

Flex-Fuel Ford Focus

In the East of England we have taken bold steps to drive biofuels forward. Earlier this year Morrisons at Norwich saw the national launch of E85 bioethanol, followed by a further four sites in Norfolk and Suffolk. Morrisons then rolled out a further five sites in Somerset. Saab also joined this launch with its new Saab Biopower. Both the Saab and the Ford flex-fuelled Focus run on ordinary petrol up to a mix of 85% ethanol. This allows me to drive my Focus FFV across the region filling up when possible with bioethanol or petrol depending on availability. Using e85 reduces my carbon impact by around 50%, something that helps me sleep slightly better – although I would much rather not have to use a car.

We were delighted when we saw that Lotus developed its Exige 265E, converted to run on E85, demonstrating that again given the opportunity the people in the region can drive forward innovation.

Again in the East Anglia region, it would also be remiss to not mention the exploits of British Sugar, alongside partners BP and Du Pont, who are currently building the world's first biobutanol plant at Wissington. It is anticipated that this will be the production summer of 2007. Given more space I would also look to the Universities and Research Institutes of the region all actively researching in the biofuels arena. Also we haven't explored biodiesel which is also clearly an rapidly emerging proposition.

Ultimately I see this article as something I hope will lead you to look into further. I have tried to set the context of climate change and the need for alternatives and leave you understanding the issues we all face and allow you to investigate how you can meet challenges. I have done all this without exploring the key issue that I assume most readers will respond to – economics.

Since 1975, we have been burning more oil per year than we have found. I would suggest that given the last 50 years of searching we have already discovered all the big oil discoveries, a hypothesis that is confirmed by any graph showing the diminishing returns from oil exploration.

This brings us to the Peak Oil debate. Basically, as reflected many years ago in the US crude oil and over the last five years in UK North Sea Gas reserves, there comes a point with a finite resource when you go from maximum output to reduced output. Oil multinationals looking into this issue predict that global peak oil output will be reached in the 2020s. Some commentators speculate that it is happening now or will do in the next few months. I would suggest that it is clear that oil will play a significant part in the global economy for several decades to come but that it is obvious that alternatives will need to come to market in the near to medium term. That is why I work in renewables and it why I suggest all organisations need to look very closely at matching experience and capabilities with this new global opportunity.

Saab 9-5 BioPower

Source: James Beal, Renewables East
www.renewableseast.org.uk

Group Lotus plc

Head office:
Lotus Cars Ltd
Hethel
Norwich
Norfolk
NR14 8EZ
United Kingdom

Editor: Peter Morgan
E: proactive@lotuscars.co.uk

just-auto.com

Head office:
C/o Aroq Ltd
Seneca House
Buntsford Park Road
Bromsgrove
B60 3DX
United Kingdom

Contact: Mike Gove
E: mike.gove@aroq.com